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Review

Health Benefits of Digital Videogames for the Aging Population: A Systematic Review

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Abstract

Objective: This article presents the results of a systematic review of the latest, state-of-the-art research on videogames designed for older adults (i.e., those aged 65 or older) and the health benefits derived from playing these games. Findings from each study that met the inclusion criteria were analyzed and summarized into emergent themes to determine the impact of digital games in promoting healthy behaviors and benefits among these older adults.
Materials and Methods: Five databases (PubMed, ScienceDirect, IEEE Xplore, ACM Digital Library, and Google Scholar) were searched for studies that evaluated interventions of videogames for older adults aged 65 and older. The initial search yielded 806 articles. After evaluating them against the inclusion criteria, 23 studies remained.
Results: Out of the 23 studies we reviewed, 20 reported the significant impact of videogame interventions on the elderly's physical health. In addition, 14 studies reported effects on the elderly's mental health. Exergame is the most popular type of game used in these videogame-based interventions. This review also includes the details of study design (e.g., type of intervention, length, frequency), population sample, and measurements used in the studies.
Conclusions: This systematic review demonstrates that videogame-based interventions are helpful in promoting physical health (i.e., balance, mobility, strength, physical fitness, and walking performance/gait parameters) and mental health (i.e., balance confidence, executive functions, reaction time, and processing speed) among older adults. It can also be used by researchers in this field to inform their design decisions. We have listed guidelines that can be used to frame future research in the area and enhance its quality.

Keywords: Videogames, Physical health, Mental health, Social health, Aging population

Introduction

With significant advances in health care and increased life expectancy in the past few decades, the population of older adults has been growing rapidly. According to the World Health Organization, the population of adults aged 65 or older in 2015 accounted for 8.5% of the world population. This number is expected to double by 2050, reaching 16.7% or 1565.8 million.[1]

People are likely to experience some degree of age-related changes when they turn 65. Evidence suggests that age-related decline includes, but is not limited to, decrements in gait parameters,[2] motor control,[3] and cognition.[4] In addition, age-related illnesses (e.g., Alzheimer's disease) are another aspect that can contribute to the frailty of older adults. These age-related changes tend to affect their health-related quality of life (HRQOL), which includes the quality of physical, mental, and social functions of a person's life.[5–7] Certain age-related changes and diseases could be slowed down or even reversed after specific training or interventions, whereas other age-related declines are consequences of unhealthy lifestyles (e.g., physical inactivity that could lead to

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type 2 diabetes),[8] which can be changed when there is early awareness, a suitable environment, and right motivation.

Various countermeasures have been set up to tackle these declines, foster healthy aging, improve HRQOL, and hence promote a healthy lifestyle. Mikus et al.[8] have shown that being physically more active by taking more steps could contribute to reducing the risk of developing type 2 diabetes. In addition, older adults who carry out physical activities can slow down their physical decline and decondition.[9,10] Taking memory training exercises could help older adults to ameliorate memory loss and its associated issues[11] and equip them with strategies[12] to cope with situations in the event that loss of memory occurs.

Recently, there has been an increasing trend to convert these training programs into videogames, because research[13–16] has shown their potential to improve physical ability (e.g., gait parameters) and cognitive performance (e.g., attention). Exergames, a type of game that requires physical activities, has become one of the most used game types for such game-based interventions. These games are aimed at helping to overcome several of the reported barriers for older users to do physical activities as they make them more appealing and can engage a broad audience across different age groups.[17]

Contribution

The main contribution of this systematic review is to analyze the latest, state-of-the-art research on the use of videogames for promoting HRQOL (i.e., physical, mental, social health benefits) among the aging population. We have been able to extract key details of the study design, type of games used in the interventions, health measurements, and results from relevant papers. Although review papers with the same focus exist in the literature, the last one was published in 2011[18] (i.e., 9 years ago). Since then, there have been rapid advances in gaming technologies and, as such, it is important to explore what the latest research shows and where it is heading toward. Our review led to finding 21 articles published after 2011. In addition, this review differs from the previous one,[18] in that it only examined studies with participants older than 65. Studies with younger populations were excluded.

Materials and Methods

The structure and sequence of this review follows the PRISMA[19] guidelines.

Eligibility criteria

To be included in this systematic review, the publication was required to: (1) have used a videogame to promote an HRQOL (physical, mental, and/or social); (2) have been written in English and appeared in a professional peer-reviewed journal or conference; (3) have recruited participants that are 65 or older; (4) have involved both genders for analysis to reduce bias; and (5) have been rated at least to be of ''moderate quality'' based on the Quality Assessment Tool for Quantitative Studies.[20] No additional exclusionary criteria were employed.

Information sources and search strategy

Articles were extracted in April 2018 by using five databases (PubMed, ScienceDirect, IEEE Xplore, ACM Digital Library, and Google Scholar). Keywords were identified based on previous reviews on the use of videogames to elicit health benefits.[18,21,22]

Keywords for Game were: ''Digital,'' ''Video,'' ''Digital video,'' ''Computer,'' ''Virtual,'' ''Mobile,'' ''Arcade,'' ''Handheld,'' ''Casual,'' ''Serious,'' ''Virtual reality,'' ''Augmented Reality,'' ''Interactive,'' ''Health,'' ''Simulation,'' ''Online,'' ''Console,'' ''Persuasive,'' ''Action-adventure,'' ''Sports,'' ''Escape,'' ''First person shooter,'' ''Third person shooter,'' ''Role-playing,'' ''Real-time strategy,'' ''Medieval,'' ''Adventuring''; for Older adult were: ''Older adult,'' ''Aged,'' ''Elderly,'' ''Senior,'' ''Aging,'' ''Aging,'' ''Aged people,'' ''Older people,'' ''Geriatrics''; and for health related were: ''Fall,'' ''Balance,'' ''Cogniti*,'' ''Mental,'' ''Physical,'' ''Social,'' ''Psychological,'' ''Exercise,'' ''Anxiety,'' ''Depression,'' ''Social isolation,'' ''Rehabilitation,'' ''Musculoskeletal,'' ''Stroke,'' ''Movement disorder.''

The following combinations of keywords were used across the selected search engines: Digital or Video or Digital video or Computer or Virtual or Mobile or Arcade or Handheld or Casual or Serious or Virtual reality or Augmented Reality or Interactive or Health or Simulation or Online or Console or Persuasive or Action-adventure or Sports or Escape or First person shooter or Third person shooter or Role-playing or Real-time strategy or Medieval or Adventuring AND Gam* AND Older adult or Aged or Elderly or Senior or Aging or Aging or Aged people or Older people or Geriatrics AND Fall or Balance or Cognitive or Cognition or Mental or Physical or Social or Psychological or Exercise or Anxiety or Depression or Social isolation or Rehabilitation or Musculoskeletal or Stroke or Movement disorder.

Selection of studies

The selection was performed through four rounds. In the first round, duplications were identified and removed. A screening of their abstract was done in the second round where articles that did not meet the eligibility criteria (1–4) were removed. Eligibility criteria (1–4) were used again in the third round, where articles were assessed through reading the whole article. In the fourth round, a quality assessment for each article was conducted by using the Quality Assessment Tool for Quantitative Studies,[20] where articles rated below ''moderate quality'' were excluded.

Data items

Each row in Tables 1 and 2 refers to a different study. The studies were summarized based on first author, description of the study, year, research design (design, duration of intervention, frequency, duration of play, setting), sample-related (sample size, dropout rate, age, gender), type of game and platform used, gaming devices, measurements of the study relevant for health, and results (Table 1). The bias risks are summarized regarding selection bias, study design, confounders, blinding, data-collection method, withdrawals, and an overall rating (Table 2). The second author helped to re-assess all items.

Table 1. Results of the Literature Survey on the Health Benefits of Videogames for the Aging Population

Study description	*Research design (design; duration of intervention; frequency; duration of play; setting)*	*Sample size (dropout) age (M/F)*	*Types of games and platforms*	*Health-related measurements*	*Findings*
Pichierri et al.[16] tested whether a 12-week dance videogame exercise regime would lead to greater changes in gait performance and fear of falling when compared with strength and balance exercises alone. (2012)	Pre-/post-test RCT; 12 weeks; twice a week; 40 minutes for ACG and 50–55 minutes for IG; hostels for the aged	IG = 15, ACG = 16 9 After dropout: IG = 86.9 (3/8) ACG = 85.6 (1/10)	Exergame; projection and dance pad	Physical: FPA (FPA protocol),[61] gait parameters (GAITRite) Mental: fear of falling (FES-I)	Physical: (1) IG had a higher improvement in gait velocity and single support time of fast walking DT condition than ACG. (2) Significant interaction in favor of IG for improvements in step time. (3) Significant improvements in fast walking performance under DT conditions (velocity, double support time, step length) was observed for the IG group only.
Soares et al.[24] evaluated the therapeutic effects of an exergame for physical rehabilitation of frail older people. (2016)	Pre-/post-test with a control group; 3 months; twice a week; 15–25 minutes; laboratory	IG = 12, CG = 12 5 After dropout: IG = 83 (4/7) CG = 80 (3/5)	Exergame; Kinect with a computer	Physical: functional mobility (TUG), balance (FRT), IPAQ, TMM (TMM equation),[62] muscle strength (dynamometers) Mental: cognitive impairment (MMSE)	Physical: only IG had significant improvements after intervention regarding functional mobility (TUG), balance (FRT), and lower and upper limb strength.
Whyatt et al.[25] tested the feasibility of their exergame on balance training for older adults. (2015)	Pre-/post-test RCT; 5 weeks; twice a week; minimum 30 minutes; sheltered accommodation and community	IG = 42, CG = 42 2 After dropout: IG = 77.18 (5/35) CG = 76.62 (20/22)	Exergame; Wii™ balance board with a laptop	Physical: balance (BBS) Mental: balance confidence (ABC)	Physical and mental: IG had significant improvements on BBS and ABC whereas CG did not.
Schättin et al.[41] compared exergame training with conventional balance training regarding executive functions and gait performance. (2016)	Pre-/post-test RCT; 8–10 weeks, total 24 sessions; 3 sessions a week; 30 minutes; senior residence dwelling	IG = 15, ACG = 14 2 After dropout: IG = 80 (8/5) ACG = 80 (7/7)	Exergame; dance platform with a computer	Physical: gait parameters (wearable sensor) Mental: prefrontal brain activity (EEG), executive functions (TAP)	Physical and mental: (1) Gait parameters (speed normal and fast walking, cadence normal walking, and stride length fast walking) improved significantly within the IG under DT conditions. (2) IG had significant improvements in executive functions regarding working memory, divided attention, set-shifting, and inhibition (TAP).

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Table 1. (Continued)

Study description	*Research design (design; duration of intervention; frequency; duration of play; setting)*	*Sample size (dropout) age (M/F)*	*Types of games and platforms*	*Health-related measurements*	*Findings*
Eggenberger et al.[50] evaluated synergistic effects of multicomponent physical exercises complemented with novel simultaneous cognitive training on cognition in older adults. (2015)	Pre-/post-test RCT with 1-year no training follow-up; 6 months; twice a week; 1 hour; clinic	IG = 30, MemoryG = 29, ACG = 30 24 After dropout: IG = 77.3 (10/14) MemoryG = 78.5 (6/16) ACG = 80.8 (9/16)	Exergame; dance mat with projection screen	Mental: set-shifting (TMT-B), working memory (executive control task), long-term visual memory (paired-associates learning task), long-term verbal memory (WMS-R), short-term verbal memory (WMS-R), attention (age concentration tests A and B), and processing speed (TMT-A and DSST)	Mental: (1) After a 6-month intervention, IG had significant improvements in cognitive performance (set-shifting, working memory, long-term visual memory, long- and short-term verbal memory, attention, and processing speed). (2) Improvements in set-shifting in favor of IG over ACG. (3) Improvement of working memory in favor of IG than MemoryG. (4) After the 1-year follow-up testing, working memory, processing speed, and long-term visual memory in IG remained unchanged, with set-shifting increasing significantly.
Duque et al.[26] evaluated the effect of a new virtual reality system on balance, falls, and fear of falling in a population of community-dwelling older subjects with a known history of falls. (2013)	Pre-/post-test RCT, with a 9-month no follow-up training; 6 weeks; twice a week; 30 minutes; hospital	IG = 30 with 97% adherence data, ACG = 40 IG = 79.3 (11/19) ACG = 75 (16/24)	Exergame; 3D virtual reality goggles	Physical: balance parameters (LOS, eyes closed on hard surface, eyes closed on foam, optokinetic stimuli, vertical VVC, and horizontal VVC) Mental: fear of falling (SAFFE)	Physical and mental: (1) IG had significant improvement in balance (LOS, eyes closed on hard surface, eyes closed on foam, optokinetic stimuli, vertical VVC, and horizontal VVC). However, no significant differences were found between groups. (2) After 9 months of no training, IG showed significantly higher balance performance (LOS, optokinetic stimuli, and both vertical and horizontal VVC) than ACG. (3) Balance performance with eyes closed on hard surface and on foam returned to the pre-training levels. (4) IG had a significantly lower fear of falling score than ACG.

(*continued*)

Table 1. (Continued)

Study description	*Research design (design; duration of intervention; frequency; duration of play; setting)*	*Sample size (dropout) age (M/F)*	*Types of games and platforms*	*Health-related measurements*	*Findings*
Lai et al.[27] evaluated the effects of an interactive videogame-based training on the balance of older adults. (2013)	Randomized and single-blind crossover trial; 12 (6 weeks each group); three times a week; 30 minutes; hospital	Group A = 15, Group B = 15 0 After dropout: Group A = 70.6 (7/8) Group B = 74.5 (6/9)	Exergame; XMSS with console	Physical: balance (BBS, UST, SA, and SV of COP of bipedal stance with eyes open and closed), functional mobility (TUG) Mental: balance confidence (MFES)	Physical and mental: (1) Group A: BBS, MFES, TUG, and SV with eyes open and closed improved significantly compared with baseline (week 0). Group B: All outcome measures except UST improved significantly compared with before the intervention (week 6) and with baseline (week 0). (2) Six-week follow-up for Group A: BBS and TUG showed significant improvement compared with the baseline (week 12).
Jorgensen et al.[39] assessed the effects of a Nintendo® Wii-based training game on muscle strength and postural balance in older adults. (2013)	Single-blinded pre-/post-test RCT; 10 weeks; twice a week; 30–40 minutes; community	IG = 28, CG = 30 2 IG = 75.9 (9/19) CG = 73.7 (9/21)	Exergame; Nintendo Wii	Physical: lower limb muscle strength (leg press device), functional mobility (TUG), leg strength, and endurance (30-second repeated standing from/sitting on a chair test) Mental: fear of falling (short FES-I)	Physical and mental: (1) IG showed significant improvements on lower limb muscle strength, TUG, short FES-I, and 30-second repeated chair stand test. (2) IG led to substantial improvements in TUG, short FES-I, and 30-second repeated chair stand test compared with CG.
Eggenberger et al.[33] investigated whether exercise training induces functional brain plasticity during challenging treadmill walking and elicits associated changes in cognitive executive functions. (2016)	Pre-/post-test RCT; 8 weeks; three times a week; 30 minutes; clinic	IG = 22, ACG = 20 9 After dropout: IG = 72.8 (7/12) ACG = 77.8 (5/9)	Exergame; pressure sensitive platform and a screen	Physical: lower extremity functioning (SPPB) Mental: prefrontal cortex activity (EEG), executive functions (Shifting [TMT-B], inhibition [SCWT], working memory [executive control task]), general cognitive ability (MoCA), processing speed (TMT-A), fear of falling (FES-I), and depression (GDS)	Physical and mental: (1) After intervention, both groups have improved their performance regarding executive function (TMT-B, SCWT), general cognition (MoCA), processing speed (TMT-A), and physical functioning (5-s chair stand). (2) Both interventions significantly reduced left and right hemispheric PFC oxygenation during the acceleration of walking, whereas the IG group showed a more significant reduction at the end of the 30-second walking task compared with the ACG group in the left PFC.

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Table 1. (Continued)

Study description	*Research design (design; duration of intervention; frequency; duration of play; setting)*	*Sample size (dropout) age (M/F)*	*Types of games and platforms*	*Health-related measurements*	*Findings*
de Bruin et al.[42] investigated the effects of a dance exergame against usual care physical interventions in a group of older adults regarding balance, gait performance, and fear of falling. (2011)	Pilot, pre-/post-design; 12 weeks; two times a week; 45–60 minutes; assisted living facilities	IG = 20, ACG = 15 7 After dropout: IG = 86.8 (3/14) ACG = 85.2 (3/8)	Exergame; dance pad with computer	Physical: gait parameters (GAITRite), physical performance (ETGUG) Mental: fear of falling (FES-I)	Physical and mental: (1) Fear of falling and stride time under DT conditions decreased significantly in IG, whereas the ACG remained unchanged. (2) IG had significant improvements in DT conditions of costs of walking (velocity, stride time, and step length).
Mugueta-Aguinaga and Garcia-Zapirain[34] investigated the effect of an exergame on reducing frailty risk on older adults. (2017)	Pre-/post-test RCT; 3 weeks; three times a week; 20 minutes; not mentioned	IG = 20, CG = 20 1 After dropout: IG = 85.47 (8/12) CG = 83.11 (8/11)	Exergame; Kinect, computer, and a monitor or TV	Physical: frailty (SPPB)	Physical: Study group increased in SPPB scores whereas those from the control group decreased.
Chen[28] assessed the effects of a game with Kinect on physiological and standing stability in older adults. (2016)	Crossover, pre-/post-design; 12 weeks (6 weeks for each groups); two times a week; 30 minutes; not mentioned	Group A = 21, Group B = 22 3 After dropout: Group A = 69.7 (10/10) Group B = 71.2 (9/11)	Exergame; Kinect with a monitor	Physical: balance (FRT, FSST, and UST)	Physical: All participants had significant improvements regarding FRT and UST after playing the exergame for 6 weeks.
Schoene et al.[48] investigated the effectiveness of a step-based exergame on cognitive functions associated with falls in older adults. (2015)	Single-blinded pre-/post-test RCT; 16 weeks; three times a week; 20 minutes; home	IG = 47, CG = 43 9 IG = 82 (16/31) CG = 81 (14/29)	Exergame; electronic step pad with computer and TV as screen	Mental: processing speed (letter-digit test, a light stimulus and the depression of switch test, and CSRT), attention and set-shifting (TMT-A, TMT-B, TMT B/A), inhibition (Victoria Stroop task and ANT), divided attention (TUG), working memory (digit-span backward), visuo-spatial performance (mental rotation task), depression (PHQ-9), and fear of falling (Icon-FES)	Mental: (1) IG had significant improvements on inhibition (ANT_executive), divided attention, reaction time (CSRT-MT), and depressive symptoms when compared with baseline. (2) Compared with CG, IG improved significantly for processing speed-related measures (hand reaction time, digit-letter mean and minimum time, and CSRT), accuracy in visuo-spatial performance (mental rotation task), and fear of falling (Icon-FES).

(*continued*)

Table 1. (Continued)

Study description	*Research design (design; duration of intervention; frequency; duration of play; setting)*	*Sample size (dropout) age (M/F)*	*Types of games and platforms*	*Health-related measurements*	*Findings*
Studenski et al.[43] evaluated the feasibility and safety of using an interactive dance videogame for promoting physical function and quality of life on healthy older adults. (2010)	Single group, pre-/post-design; 3 months; two times a week; 30 minutes; senior living centers	36 11 After dropout: 80.2 (5/20)	Exergame; dance pad with projection screen	Physical: physical fitness (SPPB), walking performance (narrow walk time), SF-36 Mental: balance confidence (ABC), SF-36, digit symbol substitution test	Physical and mental: Participants had significant improvements in narrow walk time, balance confidence, and SF-36 mental health scores.
Chen et al.[29] assessed whether a set of uni-axial force plate incorporated a videogame-based power training program and can train lower limb muscle power. (2012)	Pre-/post-test RCT; 6 weeks; twice a week; 30 minutes; clinic	45 5 After dropout: IG = 76.4 (14/6) ACG = 75.40 (11/9)	Exergame; uni-axial force plate and a computer	Physical: muscle power (force plate), risk of falling (POMA, FRT, FTSS, and TUG) Mental: balance confidence (MFES)	Physical and mental: IG had a significant improvement in lower limb muscle power, balance (POMA, FRT, TUG, and FTSS), and fear of falling (MFES).
Eggenberger et al.[35] compared two variations of multicomponent simultaneous cognitive–physical training with an exclusive physical program and to evaluate the effects of these programs primarily on DT gait performance in healthy older adults. (2015)	RCT with 1-year nonintervention follow-up, pre-/post-test; 6 months; two times a week; 1 hour; clinic	IG = 30, MemoryG = 29, AG = 30 18 after 6-month intervention After dropout: IG = 77.3 (10/14) MemoryG = 78.5 (6/16) AG = 80.8 (9/16)	Exergame; dance platform with projection screen	Physical: Gait analysis (GAITRite), SPPB, functional aerobic endurance performance (6-MWT) Mental: FES-I, depression (GDS)	Physical: IG showed a significant advantage compared with AG in DT costs of step time variability at fast walking. IG reduced step time significantly at fast walking under ST when compared with MemoryG. All groups improved significantly in gait, functional fitness, and reduced fall frequency. Velocity preferred-DT and step-time preferred-DT showed significant improvement at follow-up, only single-task fast walking, gait variability at preferred walking speed, and SPPB reduced at follow-up.
Ben-Sadoun et al.[36] evaluated the usability and short-term training effects of an exergame designed for elderly subjects with cognitive impairment. (2016)	Two-group pre-/post-test; 5 weeks; three times a week (13 in total); 10 hours in total; not mentioned	NDG = 10, HECG = 8; 0 NDG = 78.5 (6/4) HECG = 71.4 (3/5)	Exergame; desktop computer with Kinect	Physical: physical fitness (SPPB, 10-MWT, TUG, and 6-MWT) Mental: cognitive function (MMSE, FAB, SCB, TMT-A, TMT-B, DSST, and DMS48)	Physical and mental: (1) NDG subjects showed lower performance compared with HECG participants in tests of both physical fitness and cognitive functions. (2) Both groups have improved performance in SPPB through 13 sessions of training. However, only healthy objects have improved TMT (A and B) performance.

(*continued*)

Table 1. (Continued)

Study description	*Research design (design; duration of intervention; frequency; duration of play; setting)*	*Sample size (dropout) age (M/F)*	*Types of games and platforms*	*Health-related measurements*	*Findings*
Ellmers et al.[30] aimed at determining whether it is possible to recalibrate perceptions of a disparity between perceived and actual balance abilities among older adults through a short-term exergaming intervention. (2018)	Single-group design, pre-/post-test; 4 weeks; two times a week; 30 minutes; sheltered accommodation	26 6 78.1 (5/21)	Exergame; Nintendo Wii Fit™	Physical: postural control capabilities (COPE) Mental: fear of falling (FES-I)	Physical: Participants had a significant better postural control capabilities (COPE) after the short-term intervention.
Rogan et al.[40] evaluated the effects of a combined innovative training regime consisting of stochastic resonance whole-body vibration and a dance videogame on physical performance and muscle strength in older adults. (2016)	Single-blind pre-/post-test RCT; 8 weeks; three times a week; not mentioned; care center	IG = 16, shamG = 14 0 After dropout: IG = 90.4 (6/10) ShamG = 87.2 (4/10)	Exergame; dance pads with projection screen	Physical: lower extremity physical function (SPPB), lower body muscle strength (IMVC and IRFD)	Physical: (1) The between-groups effect showed significant values after 4 weeks and after 8 weeks in favor of IG. (2) The result showed significant between-groups effects in IG on muscle strength (sub-phases of IMVC 30, 100, and 200 ms and sub-time phases of IRFD 0–30, 0–50, 0–100, and 100–200 ms) compared with the ShamG. (3) Both groups improved significantly after intervention regarding lower body muscle strength (IRFD left extension, right and left flexion).
Nicholson et al.[31] tested the effectiveness of unsupervised Nintendo Wii Fit balance training in older adults. (2015)	Two-group pre-/post-design; 6 weeks; three times a week; 30 minutes; home	IG = 19, CG = 22 0 After dropout: IG = 75.11 (7/12) CG = 73.91 (7/15)	Exergame; Nintendo Wii Fit	Physical: balance and mobility (TUG, FRT, lateral reach, single-leg balance, 30-second repeated chair stand test, and usual gait speed) Mental: fear of falling (Icon-FES)	Physical and mental: IG demonstrated significant improvements after intervention regarding TUG, left single-leg balance, lateral reach, and gait speed when compared with the CG.

(*continued*)

Table 1. (Continued)

Study description	*Research design (design; duration of intervention; frequency; duration of play; setting)*	*Sample size (dropout) age (M/F)*	*Types of games and platforms*	*Health-related measurements*	*Findings*
Pichierri et al.[44] explored whether a cognitive-motor exercise program that combines traditional physical exercise with a dance videogame can improve the voluntary stepping responses of older adults under attention demanding DT conditions. (2012)	Pre-/post-test RCT; 12 weeks; two times a week; 60 minutes; home	IG = 14, CG = 11 10 After dropout: IG = 83.6 (3/6) CG = 86.2 (3/3)	Exergame; dance pads with projection screen	Physical: motor performance (voluntary step execution test)	Physical: (1) IG had significant improvements in motor performance (step directions, some foot off, and some foot contact tasks). (2) The between-group comparison revealed significant differences for initiation time of forward steps under DT conditions and for backward steps under DT conditions in favor of the IG.
Williams et al.[32] assessed whether using the Nintendo's Wii Fit game impacts the balance of older adults. (2011)	Quasi-experimental, pilot single-group study, pre-/post-design; 4 weeks; three times a week; 20 minutes; not mentioned	22 0 83.86 (4/18)	Exergame; Nintendo Wii Fit	Physical: balance (BBS)	Physical: Participants' balance (BBS) improved significantly after the intervention.
Goldstein et al.[47] assessed the effects of playing videogames on reaction time, cognitive adaptability, and emotional responses of older adults. (1997)	Pre-/post-test RCT; 5 weeks; min 5 hours a week; not mentioned; apartments for elderly	IG = 10, CG = 12 0 After dropout: IG = 76.5 (1/9) CG = 78.7 (1/11)	Causal; Nintendo SuperNes videogame console with TV	Mental: RT (Sternberg test), inhibition (SCWT), emotional well-being	Mental: (1) IG showed a significant improvement in RT (Sternberg Test), and the RT after intervention was significantly faster among the IG than the CG. (2) On the SCWT, both the IG and CG improved significantly, but the difference between groups was not statistically significant. (3) Participants from the IG had a significantly higher positive well-being score than those in the CG.

10-MWT, 10-meter Walk Test; 6-MWT, 6-minute walk test; ABC, activities-specific balance confidence scale; ACG, active control group; AG, active group; ANT, attentional network test; B/A, ratio score of B and A; BBS, berg balance scale; CG, control group; COP, center of pressure; COPE, centre of pressure excursion; CSRT, choice stepping reaction time; DSST, digital symbol substitution task; DT, dual tasks; EEG, electroencephalogram; ETGUG, extended timed get-up-and-go; FAB, Fullerton advanced balance; FES-I, falls efficacy scale international questionnaire; FPA, foot place accuracy; FRT, functional reach test; FSST, four square step test; FTSS, five times sit to stand; GDS, geriatric depression scale; HECG, healthy elderly control group; Icon-FES, iconographical fall-efficacy scale; IG, intervention group; IMVC, isometric maximal voluntary contraction; IPAQ, international physical activity questionnaire-short form; IRFD, isometric rate of force development; LOS, limits of stability; MemoryG, memory group; MFES, modified falls efficacy scale; MMSE, mini mental state examination; MoCA, montreal cognitive assessment; MT, movement time; NDG, neurodegenerative diseases group; PFC, prefrontal cortex; PHQ-9, patient health questionnaire; POMA, Tinetti performance-oriented mobility assessment; RCT, randomized controlled trial; RT, reaction time; SA, sway area; SAFFE, Survey of Activities and Fear of Falling in the Elderly; SCB, Short Cognitive Battery; SCWT, Stroop Color and Word Test; SF-36, 36-Item Short Form Survey; ShamG, Sham group; SPPB, short physical performance battery; ST, single task; SV, sway velocity; TAP, test battery for attentional performance; TMM, total muscle mass; TMT-A, trail making test part A; TMT-B, trail making test part B; TUG, time up and go; UST, unipedal stance test; VVC, visual-vestibular condition; WMS-R, Wechsler Memory Scale-Revised; XMSS, xavix measured step system.

Table 2. Risk of Bias, Quality of Research Indicators of Each Study

	Selection bias	*Study design*	*Confounders*	*Blinding*	*Data collection*	*Withdrawals*	*Overall*
Pichierri et al.[16]	**	***	***	*	***	**	**
Soares et al.[24]	**	**	***	*	***	**	**
Whyatt et al.[25]	**	***	**	*	***	***	**
Schättin et al.[41]	**	***	***	**	***	***	***
Eggenberger et al.[50]	**	***	***	**	***	***	***
Duque et al.[26]	**	***	***	*	***	***	**
Lai et al.[27]	**	***	**	**	***	***	***
Jorgensen et al.[39]	**	***	***	**	***	***	***
Eggenberger et al.[33]	**	***	***	**	***	**	***
de Bruin et al.[42]	**	***	***	*	***	**	**
Mugueta-Aguinaga and Garcia-Zapirain[34]	***	***	***	*	***	***	**
Chen[28]	**	**	**	*	***	***	**
Schoene et al.[48]	**	***	***	**	***	**	***
Studenski et al.[43]	**	**	**	*	***	**	**
Chen et al.[29]	**	**	***	*	***	**	**
Eggenberger et al.[35]	**	***	***	**	***	***	***
Ben-Sadoun et al.[36]	**	**	**	*	***	***	**
Ellmers et al.[30]	**	**	***	*	***	***	**
Rogan et al.[40]	**	***	***	**	***	***	***
Nicholson et al.[31]	**	**	***	*	***	***	**
Pichierri et al.[44]	***	***	***	**	***	**	***
Williams et al.[32]	**	**	***	*	***	***	**
Goldstein et al.[47]	**	***	***	*	***	***	**

*, weak quality; **, moderate quality; ***, high quality.

Risk of bias in individual studies

This review includes a qualitative analysis for articles that passed the quantitative exclusion, which was performed by using the Quality Assessment Tool for Quantitative Studies.[20]

The quality assessment comprised six components: (1) selection bias, (2) study design, (3) confounders, (4) blinding, (5) data-collection method, and (6) withdrawals and drop-outs. Each component was rated as weak, moderate, or strong, and a final rating was made for each study. A study was rated as ''low quality'' if it had received two or more weak ratings; ''moderate quality'' if it had received one weak rating; and ''high quality'' if it had not received any weak ratings. Any discrepancies in terms of rating were resolved between the two reviewers. The resulting studies can be found in Table 2.

It was not possible to conduct a meta-analysis, because the number of papers dealing with a specific outcome did not meet the theoretical minimum (i.e., 2). According to a previous study,[23] ''in practice, 5 or more studies are needed to reasonably consistently achieve powers from random-effects meta-analyses that are greater than the studies that contribute to them.'' The papers that were selected based on our review requirements did not meet this condition.

Results

Study selection

The systematic inclusion process included 806 papers (218 from PubMed, 113 from ScienceDirect, 269 from IEEE Xplore, 94 from ACM Digital Library, and 112 from Google Scholar). After distilling them through inclusion and exclusion criteria, 23 papers were included in the final review and summarized in Table 1. The study selection process is summarized in Figure 1. After removing the duplicates ($N=23$), 783 articles were obtained. In the first round of screening the abstract, we excluded 660 papers because they were (1) not written in English ($N=14$), (2) out of scope of current review (e.g., they were editorials, workshops, opinions, study protocols, reports, surveys, and reviews). In total, 123 articles were included after screening their titles and abstracts.

Further exclusion included the removal of studies that (1) involved participants aged <65 ($N=49$); (2) recruited participants of a single gender or did not mention gender in their study ($N=19$); (3) failed to explicitly measure and report participants' health outcomes $p>0.05$ or did not focus on health issues ($N=24$); and (4) did not solely use digital videogames in their intervention ($N=3$).

In the last round, we excluded five articles that were rated ''low quality'' by the Quality Assessment Tool for Quantitative Studies.[20]

Study characteristics and risk of bias within studies

The first article identified was published in 1997, with the number of articles increased significantly to 23 since 2010 when interactive technologies such as Kinect and Nintendo® Wii™ became popular.

The quality of research bias of individual trials was rated either ''moderate quality'' or ''high quality,'' where 9 of them were rated ''high quality'' and 14 of them ''moderate quality.'' The results are summarized in Table 2.

Studies selected

The number of studies that reported having physical and mental health outcomes after an intervention was 20 and 18,

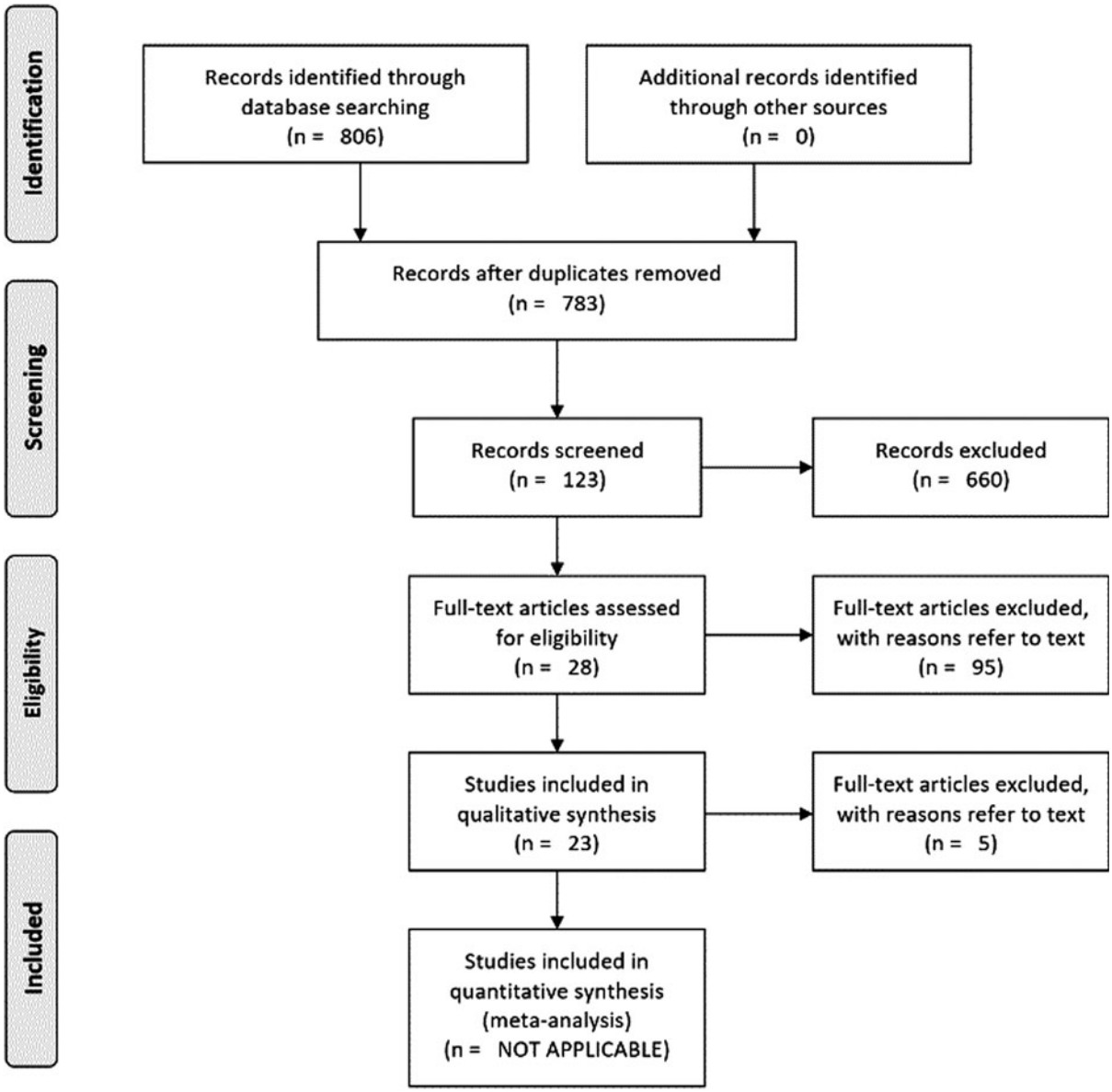

FIG. 1. Flow diagram of the inclusion process of the studies.

respectively. We did not find any studies reporting social benefits or outcomes based on our inclusion criteria. We next separated the benefits into physical and mental, and then further divided them into sub-sections. For each sub-section, we reported how many studies successfully outlined the corresponding outcome, length of the intervention, and most used assessment/device for such outcome. In addition, we included the studies showing that a videogame-based intervention was superior to an alternative active training program (e.g., physical training program) at the end of each outcome.

Physical functioning benefits

Physical functioning benefits were elicited in all studies that measured physical health. Results of the physical benefits of playing videogame are summarized next.

Balance. There were nine studies[24–32] (intervention length: 4–12 hours; $M = 6.78$) that found that playing videogames could improve the balance (both static and dynamic) of elderly users. The Berg balance scale ($N = 3$) and functional reach test (FRT) ($N = 3$) were the most used assessor-led clinical tests for assessing balance performance in these studies.

Physical fitness/functional fitness/frailty. Four studies[33–36] (intervention length: 3–24 hours; $M = 12.25$) have found improvements in physical fitness among older adults after playing videogames. Short Physical Performance Battery[37] (SPPB), which comprises a balance test, a 4-meter Walk test, and a five Chair-Rises tests, was the most used assessment test for physical fitness ($N = 4$). The SPPB is also a validated measurement in detecting frailty of these users.[38]

Strength. The outcome of improved strength (upper limb strength, lower limb strength, leg strength and endurance, muscle power) was supported in four studies[24,29,39,40]

(intervention length: 6–12 hours; $M = 9.89$). Strength was commonly assessed by some external devices such as force plates, dynamometers, and press devices. Lower limb strength was reported the most among these studies ($N = 2$).

Gait parameters and walking mobility. Improvements in gait mobility (e.g., gait speed, stepping accuracy, narrow walk time, velocity, stride time, step length, step time variability under dual tasks [DT] condition) were reported in 10 studies,[16,24,27,31,35,39,41–44] with the length of intervention ranging from 9 to 24 hours ($M = 15.4$). The timed up and go (TUG) assessment was most frequently used ($N = 2$). The GAITRite was the most widely used device for analysis of gait parameters. We found that videogame-based interventions were superior to physical training programs regarding gait velocity and single support time of fast walking under DT conditions,[16] stride time under DT conditions,[42] and DT costs of step time variability at fast walking.[35]

Mental health benefits

Mental health benefits were reported in 14 out of 18 papers. Results of mental health benefits of playing videogames are summarized next.

Balance confidence/fear of falling. Eight studies[25–27,29,31,39,42,43] (interventions length: 5–20 hours; $M = 9.83$) have reported increased confidence in body balance or decreased fear of falling. The activities-specific balance confidence[45] scale was the most used questionnaire for measuring balance confidence ($N = 2$), and the Modified Falls Efficacy Scale[46] was the most used questionnaire for measuring the fear of falling ($N = 2$). Duque et al.[26] and de Bruin et al.[42] have found that videogame-based interventions were superior to physical training programs regarding reducing the fear of falling.

Executive functions. In total, there were six papers that focused on executive functions.

Inhibition. Four studies[33,41,47,48] (intervention length: 12–25 hours; $M = 16.25$) have reported improvements in inhibition. The Stroop Word and Color Interference Test[49] was the most used task for inhibition ($N = 2$).

Set-shifting. The outcome of set-shifting was included in four studies[33,36,41,50] (interventions length: 10–48 hours; $M = 9.83$). The Trail Making Test[51] (TMT) part B (TMT-B) was the most used task for set-shifting ($N = 3$). Eggenberger et al.[50] found that their videogame-based intervention led to higher improvements in set-shifting than a physical training program.

Working memory. The outcome of working memory was concluded in two studies[41,50] (intervention length: 12–48 hours; $M = 30$). They used a test battery for attentional performance[52] (TAP) and executive control task for assessing working memory, respectively. Eggenberger et al.[50] found that their videogame-based intervention achieved a better working memory improvement than other types of memory training programs.

Divided attention. Two studies[41,48] (intervention length: 12–16 hours; $M = 14$) have reported improvements in divided attention. They used TUG and TAP to assess divided attention, respectively.

Reaction time. Improvements in reaction time was supported by two studies[47,48] (intervention length: 16–25 hours; $M = 20.5$). They used choice stepping reaction time test and the Sternberg test for measuring reaction time, respectively.

Processing speed. Improvements in processing speed were concluded by two studies[36,50] (intervention length: 10–48 hours; $M = 29$). The TMT part A (TMT-A) was the most used task for accessing processing speed ($N = 2$).

Other measured outcomes

General cognition. Eggenberger et al.[33] have found that general cognition, which was evaluated by the Montreal cognitive assessment, improved after 12 hours of a videogame-based intervention.

Emotional well-being. Goldstein et al.[47] have reported that emotional well-being, which was assessed by a Dutch version of the well-being questionnaire,[47] improved after 25 hours of a videogame-based intervention.

SF-36 mental health questionnaire. The overall score of the 36-item short-form health survey (SF-36)[53] mental health questionnaire, which measures vitality, social functioning, emotional role, and mental health, significantly increased after 12 hours of intervention.[43]

Other memory-related mental health outcomes. Eggenberger et al.[50] have found that 48 hours of a videogame-based intervention could improve long-term visual memory (paired-associates learning task),[54] long-term verbal memory (Wechsler Memory Scale—Revised),[55] and short-term verbal memory (Wechsler Memory Scale—Revised).

Synthesis of results

Experiment details. Fourteen studies applied a randomized controlled trial (RCT). The following experiment designs were also used: two-group design without randomly assigning participants ($N = 3$), one-group design ($N = 3$), crossover design ($N = 2$), and quasi-experimental single-group design ($N = 1$). Nine of the reviewed articles applied a single-blinded design, where all of them blinded their participants to the outcome. All 23 articles used validated and reliable instruments for measuring health outcomes. All articles involved pre-/post-test design.

Intervention details. The duration of interventions ranged from 3 to 24 weeks ($M = 9.35$ weeks, SD = 5.73). A month was considered 4 weeks long if the paper reported duration to be month-based. The average number of sessions of each article was 22.36 (SD = 12.49), which ranged from 9 to 48 sessions. The average duration of each study was 13.58 hours (SD = 10.31), ranging from 3 to 25 hours. Ten studies were performed at the participants' residence place, at either a facility specializing in elderly care or their actual home. Seven were conducted in a place that required participants to travel, with six in a clinic and hospital setting and one in a research lab setting.

Sample details. All studies included participants of both genders, where the average percentage of the females in each study is 64.69% (SD = 18.86%). The number of participants in each study ranged from 18 to 90 participants ($M = 44.30$, SD = 23.67). The mean age of participants in each study in the selected research literature is 79.27 years old (SD = 4.77). The average dropout rate is 11.73% (SD = 12.06%).

Game and platform details. Exergames ($N = 22$) were the most frequently used type of games that mainly investigated physical aspects (i.e., balance, strength, mobility) with a potential to improve balance confidence/fear of falling. Exergames could also help to improve other mental health aspects when they contained cognitive tasks/elements. Besides exergames, casual games ($N = 1$) were also used in the interventions. Eight articles used a dance pad/platform in their intervention. The Nintendo Wii Fit™ balance board ($N = 4$) and Kinect ($N = 4$) were the second most used types of equipment. Among these, only Kinect is capable of full-body motion tracking.

Meta-analysis. Previous research[23] has suggested that ''in practice, 5 or more studies are needed to reasonably consistently achieve powers from random-effects meta-analyses that are greater than the studies that contribute to them. Not only is statistical inference under the random-effects model challenging when there are very few studies but also less worthwhile in such cases.'' Therefore, it was not feasible to perform a meta-analysis on balance (FRT, $N = 3$), physical fitness ($N = 3$), strength ($N = 2$), gait parameters ($N = 2$), confidence of balance ($N = 2$), and fear of falling ($N = 2$). The low number of papers examining a specific outcome ($N = 1$) made a meta-analysis impossible for (1) general cognition, (2) emotional well-being, (3) SF-36 mental health questionnaire, and (4) other memory-related mental health outcomes.

In addition, different metrics used for the same outcome have likewise led to a low number of papers ($N = 1$) for outcomes such as working memory, divided attention, reaction time, and processing speed. As such, it was not feasible to conduct a meta-analysis.

Discussion

Summary of the evidence

This article has summarized and analyzed the findings of 23 research articles, with 9 rated as ''high quality'' and 14 rated as ''moderate quality'' based on the Quality Assessment Tool for Quantitative Studies.[20] Because they did not use single- or double-blinded experiment design, 14 articles were rated as ''moderate quality.'' We recommend blinding the participants instead of investigators—it is more difficult to blind the investigators, as they often supervise and conduct the training and assessments.[16,33,44,50]

Regarding physical health outcomes, our review has found that playing videogames could result in improvements in users' balance[24–32] ($N = 9$), functional mobility[24,27,31,39,44] ($N = 5$), gait parameters[16,35,41–43] ($N = 5$), physical fitness[33–36] ($N = 4$), and body strength[24,29,39,40] ($N = 4$). Among these studies, we have found that videogame-based interventions could lead to significantly greater improvements than traditional physical training programs when it comes to gait velocity and single support time of fast walking under DT conditions,[16] stride time under DT conditions,[42] and DT costs of step time variability at fast walking.[35]

Regarding mental health outcomes, our review has found that game-based interventions have the potential to improve balance confidence (or decrease fear of falling)[25–27,29,31,39,42,43] ($N = 8$), executive functions [inhibition[33,41,47,48] ($N = 4$), set-shifting[33,36,41,50] ($N = 4$), working memory[41,50] ($N = 2$), divided attention[41,48] ($N = 2$), reaction time[47,48] ($N = 2$), and processing speed[36,50] ($N = 2$)]. Other outcomes are general cognition,[33] emotional well-being,[47] overall SF-36 mental health,[53] long-term visual memory, long-term verbal memory, and short-term verbal memory.[50] In addition, we found that videogame-based interventions could lead to significantly greater improvements in balance confidence[26,42] and set-shifting[50] than a physical training program. The former also outperformed a memory training program in improving the working memory of elderly users.[50]

This review has not found enough evidence to conclude that there are effects of a videogame-based intervention on social inclusion or interaction for the aging population, because no studies met the inclusion criteria. There are two possible reasons: (1) The setup of these type of studies is not as easy as that of those targeting physical and mental outcomes, because measuring social inclusion would require some type of long-term investigation with at least two older adults playing a game together; and (2) there might have been a lack of using keywords that are related to social well-being in the literature.

In addition to the findings cited, our review has pointed out two additional issues. First, we observed that existing studies do not report follow-up studies/results. Several studies[56,57] have shown that the health benefits that were obtained from videogame interventions, just like other training programs, would vanish if there was no further follow-up training after a certain period. Conducting follow-up experiments and reporting their results could benefit the field and help design improved interventions and gaming experiences.

Second, Ben-Sadoun et al.[36] have reported that older adults with cognitive impairment had lower improvements in physical fitness and cognitive function tests compared with healthy older adults. Therefore, it may be important to prescreen participants before assigning them to an experimental group. It is also useful for researchers to conduct and publish this type of comparison studies to help developers and designers to better understand the similarities and differences when designing and testing games for unhealthy and healthy older adults.

Regarding the gaming platforms and devices, we found an increasing trend in using the Kinect ($N = 4$) to assist and promote health benefits compared with previous reviews.[18] There are several advantages of using the Kinect, as opposed to other similar devices, such as the Nintendo Wii. For example, one Kinect can track multiple players,[58] and can also be used to check for possible falls,[59] and in seated-based exergames (e.g., wheelchair-based),[60] which could allow users to perform exercises at home without the need to be standing and, in the case of weaker elderly users, without any external assistance.

Guidelines for future research

In this section, we provide some key guidelines for researchers in this field, which could help make the interventions more effective.

Enriching the study quality. The quality of studies can be improved by (1) applying an RCT with an active control group, reporting the randomization procedures; (2) blinding participants to the expected study outcome; (3) using validated and reliable health measurements as non-validated/customized measurements could weaken the study; (4) using a larger sample size (a power analysis should be performed before recruiting participants and if possible, we suggest to have an additional 11% of the desired sample size because this is the average dropout rate based on our review); and (5) reporting age, dropout rates, and gender details of the participants whenever possible.

Getting the desired outcome(s). (1) *Exergames* should be the preferred option, followed by *casual games*. The data seem to support the use of an exergame consisting of cognitive elements/tasks that not only improve physical well-being but can also enhance physiological-related health. (2) The included protocols on average consist of two to three 30–40 minute sessions per week for $\sim$9 weeks. Data obtained from our investigation showed that the intervention should last at least 22 sessions and 13.5 hours of training. This finding may provide recommendations with respect to duration of a single session, frequency of sessions, and period of the intervention. However, the total duration of training for each intervention may differ from one to another depending on the target health outcomes (e.g., 6.8 hours for balance improvement whereas 10 hours for improving balance confidence).

Other guidelines. The following guidelines are useful to follow: (1) Considering the potential difficulties for older adults to travel from their place to an external experimental venue, the data seem to indicate that it is more ideal/efficient for researchers to visit the participants in their natural place of residence to conduct any experiments; (2) screen participants to gather their health situation before randomly assigning them to the intervention groups; and (3) perform follow-up studies several weeks/months after the intervention.

Limitations

This review has two limitations. First, there could have been some publication and language bias, given that we considered only interventions described in published studies and restricted our search to English language publications available in the main research databases. Second, there is a potential that our selected keywords and inclusion criteria may have limited the number of studies, though we attempted to be as encompassing as possible.

Conclusion

This review demonstrates that using videogame-based interventions can help promote HRQOL, physical and motor skills (i.e., balance, mobility, strength, physical fitness, and walking performance/gait parameters), and mental health (i.e., balance confidence, executive functions, reaction time, processing speed, and other physiological aspects). Among the 23 articles included in our review, 20 of them had reported at least one physical outcome, whereas 14 of them had described at least one mental health outcome.

We have also found that videogame-based interventions could outperform traditional training programs regarding walking performance/gait parameter, balance confidence/fear of falling, and executive functions (i.e., set-shifting, working memory). However, our review could not find any articles that reported direct social health outcomes. Given the importance of social aspects in the elderly's health, social outcomes should be an important part of future research in videogame-based interventions. Overall, there have been a lot of articles published since the previous review conducted in this field in 2011 and there has been considerable development in using videogames and gameplay activities to promote the physical and mental health conditions of elderly adults.

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